

1 APPARATUS AND METHOD FOR OBTAINING 3D IMAGES

2

3 The present invention relates to apparatus and a method
4 for creating a three dimensional image, and
5 particularly, but not exclusively, to apparatus and a
6 method for creating a three dimensional image for use
7 in surveying.

8

9 Conventional survey equipment typically measures the
10 distance, bearing and inclination angle to a target
11 (such as a tree, electricity pylon or the like) or a
12 target area, with reference to the position of a user.
13 While this information is useful, it would be
14 advantageous to create a three-dimensional (3D) image
15 of the target and/or target area.

16

17 In addition, conventional sighting devices which are
18 used to select a target to be surveyed often result in
19 false surveys being made as the target is often not
20 correctly identified.

21

22 There are a number of conventional techniques which are
23 capable of generating a three-dimensional (3D) image
24 from photographs. One such technique is
25 stereophotography (SP). SP uses two simultaneous

1 images taken by two cameras positioned at fixed points.
2 The two fixed points are precisely spaced apart along a
3 baseline distance.

4
5 However, this conventional technique has a number of
6 associated disadvantages. Firstly, the pictures are
7 not direct to digital, which creates difficulties in
8 manipulating the images after they have been taken.
9 The images typically require to be ortho-corrected and
10 the method itself is generally slow and can be
11 expensive due to the precision cameras required.

12
13 According to a first aspect of the present invention
14 there is provided an apparatus comprising an imaging
15 device, a range finder, and a processor capable of
16 receiving and processing image and range signals to
17 construct a three-dimensional image from said signals.

18
19 According to a second aspect of the present invention
20 there is provided a method of generating a three-
21 dimensional image of a target area, the method
22 comprising the steps of providing an imaging device,
23 providing a range finder, operating the imaging device
24 to provide an image of the target area, and
25 subsequently measuring the distance to each of a
26 plurality of points by scanning the range finder at
27 preset intervals relating to the points.

28
29 The imaging device is preferably a camera, typically a
30 digital video camera, and preferably a charge-coupled
31 device (CCD) video camera. Alternatively, the camera
32 may comprise a digital camera. The camera is
33 preferably capable of zoom functions. This allows
34 targets which may be some distance from the apparatus
35 to be viewed more accurately and/or remotely.

36

1 The apparatus typically includes a display device to
2 allow a user to view a target area using the imaging
3 device. The display device typically comprises a VGA
4 eyepiece monitor, such as a liquid-crystal display
5 (LCD) or flat panel display. The display device may
6 alternatively comprise a VGA monitor. This offers the
7 advantage that an image of the target may be viewed by
8 the user to ensure that the correct target has been
9 selected. Also, the apparatus may be operated remotely
10 using the camera to view the target area.

11
12 The apparatus preferably includes a pan and tilt unit
13 for panning and tilting of the range finder and/or
14 camera. The pan and tilt unit typically comprises a
15 first motor for panning of the range finder and/or
16 camera, and a second motor for tilting of the range
17 finder and/or camera. The pan and tilt unit typically
18 includes first and second digital encoders for
19 measuring the angles of pan and tilt respectively. The
20 first and second motors are typically controlled by the
21 processor. The outputs of the first and second
22 encoders is typically fed to the processor. This
23 provides a feedback loop wherein the motors are
24 operated to pan and tilt the range finder and/or camera
25 through the generated horizontal and vertical angles.
26 The encoders may then be used to check the angles to
27 ensure that the range finder and/or camera were panned
28 and tilted through the correct angles.

29
30 The image is preferably digitised, wherein the image
31 comprises a plurality of pixels. Optionally, the image
32 may be a captured image. The target is typically
33 selected by selecting a plurality of pixels around the
34 target, using, for example, a mouse pointer. This
35 produces x and y coordinates for the target pixels and
36 defines a target area eg a building or a part thereof.

1
2
3 Typically, the range finder is preferably a laser range
4 finder. Preferably, the laser range finder is bore-
5 sighted with the camera. This, in conjunction with the
6 eyepiece monitor used to identify the target area,
7 offers the advantage that the user can be sure that the
8 target area he has selected will be captured by the
9 camera. In addition, any subsequent calculations made
10 by the processor do not require an offset between the
11 camera and the range finder to be considered.

12
13 Preferably, the apparatus includes a compass and an
14 inclinometer and/or gyroscope. These allow the bearing
15 and angle of inclination to the target to be measured.
16 These are preferably digitised to provide data to the
17 processor.

18
19 Optionally, the apparatus further includes a position
20 fixing system for identifying the geographical position
21 of the apparatus. The position fixing system is
22 preferably a Global Positioning System (GPS) which
23 typically includes a Differential Global Positioning
24 System (DGPS). This provides the advantage that the
25 approximate position of the user can be recorded (and
26 thus the position of the target using the measurements
27 from the range finder and compass, where used.
28 Preferably, the GPS/DGPS facilitates the time of the
29 survey to be recorded.

30
31 The apparatus is typically mounted on a mounting
32 device. The mounting device typically comprises
33 headgear which may be worn on the head of a user. The
34 headgear typically comprises a hard-hat type helmet.
35 Alternatively, the apparatus may be located within a
36 housing. The housing is typically a hand-held device.

1 Optionally, the mounting device may be a tripod stand
2 or a platform which forms part of an elevation system,
3 wherein the apparatus is elevated to allow larger areas
4 to be surveyed.

5

6 Optionally, the apparatus may be operated by remote
7 control.

8

9 The compass is preferably a digital fluxgate compass.

10

11 The apparatus is typically controlled by an input
12 device. The input device is typically used to activate
13 the apparatus, and may be a keyboard, keypad, penpad or
14 the like. Typically, the input device facilitates
15 operation of a particular function of the apparatus.
16 The input device is typically interfaced to the
17 processor via a standard keyboard input.

18

19 The GPS/DGPS is preferably integrally moulded within
20 the helmet.

21 The method typically includes the additional step of
22 selecting the target area to be surveyed using the
23 imaging device.

24

25 The method typically includes any one, some or all of
26 the further steps of

27 obtaining a focal length of the camera;

28 obtaining a field of view of the camera;

29 calculating the principal distance of the camera;

30 obtaining the horizontal offset and vertical

31 offset between an axis of the camera and an axis of the
32 laser;

33 calculating the horizontal and vertical offsets in
34 terms of pixels;

35 calculating the difference between the horizontal
36 and vertical offsets in terms of pixel and the x and y

1 coordinates of the target pixel; and
2 calculating the horizontal and vertical angles.
3
4 Optionally, the method typically includes one, some or
5 all of the further steps of
6 instructing the pan and tilt unit to pan and tilt
7 the range finder and/or camera through the vertical and
8 horizontal angles;
9 measuring the horizontal and vertical angles using
10 the encoders;
11 verifying that the angles through which the range
12 finder and/or camera are moved is correct;
13 obtaining horizontal and/or vertical correction
14 angles by subtracting the measured horizontal and
15 vertical angles from the calculated horizontal and
16 vertical angles;
17 adjusting the pan and tilt of the range finder
18 and/or camera if necessary; and
19 activating the range finder to obtain the range to
20 the target.

21
22 Preferably, the method includes the additional step of
23 correlating the position of the pixels in the digital
24 picture with the measured distance to each pixel. This
25 generates a set of x, y and z co-ordinates for all of
26 the pixel points which may be used to generate a three
27 dimensional image of the target area.

28
29 Embodiments of the present invention shall now be
30 described, by way of example only, with reference to
31 the accompanying drawings in which:-

32 Fig. 1 is a schematic representation of an image
33 capture and laser transmitter and receiver unit in
34 accordance with, and for use with, the present
35 invention;

36 Fig. 2 shows schematically a first embodiment of

1 an apparatus;
2 Fig. 3 shows an exploded view of the apparatus of
3 Fig. 2 in more detail;
4 Fig. 4 shows a simplified schematic illustration
5 of a digital encoder;
6 Fig. 5 schematically shows the apparatus of Figs 2
7 and 3 in use;
8 Fig. 6 is a schematic representation of the
9 display produced on a computer screen of a freeze
10 frame image produced by a digital camera;
11 Fig. 7 is a simplified schematic diagram of inside
12 a digital camera;
13 Fig. 8 is a simplified diagram illustrating how a
14 principal distance (PD) may be calculated;
15 Fig. 9 is a simplified diagram illustrating the
16 offset between the laser and the camera in use;
17 Fig. 10 is a schematic representation illustrating
18 a horizontal offset H_{offset} outwith the camera;
19 Fig. 11 is a schematic representation illustrating
20 a horizontal distance l_x in terms of pixels,
21 corresponding to H_{offset} , within the camera;
22 Fig. 12 is a simplified diagram of a freeze frame
23 image showing an object;
24 Fig. 13 is a schematic representation illustrating
25 the relationship between a horizontal distance d_x ,
26 a principal distance PD and an angle θ ;
27 Fig. 14 is a simplified diagram illustrating the
28 principle of calculating pixel x and y co-
29 ordinates from horizontal and vertical angles of
30 and range to the pixel;
31 Fig. 15 is a simplified diagram illustrating the
32 relationship between horizontal and vertical
33 angles of and range to the pixel and three
34 dimensional co-ordinates of the pixel;
35 Fig. 16 is a print of the triangular framework
36 used to recreate a 3D image of a bitmap

1 photograph;
2 Fig. 17 shows a print of a 3D image which used a
3 bitmap photograph superimposed on the framework of
4 Fig. 16;
5 Fig. 18 is a representation of an alternative
6 mounting device for the apparatus according to a
7 first aspect of the present invention;
8 Fig. 19a is a schematic representation of a
9 vehicle provided with an elevating arm and
10 apparatus showing the position of the apparatus
11 when the vehicle is moving;
12 Fig. 19b is a schematic representation of the
13 vehicle of Fig. 19a with the apparatus deployed on
14 the arm;
15 Fig. 19c is a schematic representation of the
16 vehicle of Figs 19a and 19b on a slope with the
17 apparatus deployed on the arm;
18 Figs 20a and 20b are respective rear and side
19 views of the apparatus deployed on the arm;
20 Figs 21a and 21b are respective side and plan
21 elevations of the vehicle of Figs 15a to 15c
22 illustrating the apparatus being used to profile
23 the ground in front of the vehicle;
24 Fig. 22 is a schematic view of a second embodiment
25 of a mounting device;
26 Figs 23 to 27 show a hand-held housing for the
27 apparatus according to a first aspect of the
28 present invention; and
29 Figs 28 to 30 show the hand-held housing of Figs
30 23 to 27 in use.

31
32 Referring to the drawings, Fig. 1 shows a schematic
33 representation of an image capture and laser
34 transmitter and receiver unit 10 which forms part of
35 the apparatus in accordance with a first aspect of the
36 present invention. Unit 10 includes a laser 12 (which

1 typically forms part of a laser range finder), where
2 the laser 12 generates a beam of laser light 14. The
3 laser 12 is typically an invisible, eyesafe, gallium
4 arsenide (GaAs) diode laser which emits a beam
5 typically in the infra-red (ie invisible) spectrum.
6 The laser 12 is typically externally triggered and is
7 typically capable of measuring distances up to, or in
8 excess of, 1000 metres (1 km). It should be noted that
9 any suitable type of laser may be used.

10

11 The beam 14 is reflected by a part-silvered prism 16 in
12 a first direction substantially perpendicular to the
13 direction of the initial beam 14, thereby creating a
14 transmit beam 18. The transmit beam 18 enters a series
15 of transmitter optics 20 which collimates the transmit
16 beam 18 into a target beam 22. The target beam 22 is
17 reflected by a target (schematically shown in Fig. 1 as
18 24) and is returned as a reflected beam 26. The
19 reflected beam 26 is collected by a series of receiver
20 optics 28 and directs it to a laser light detector 30.
21 The axes of the transmit and receiver optics 20, 28 are
22 calibrated to be coincident at infinity.

23

24 Signals from the detector 30 are sent to a processor
25 (not shown in Fig. 1), the processor typically forming
26 part of a computer. The processor calculates the
27 distance from the unit 10 to the target 24 using a
28 time-of-flight principle. Thus, by dividing the time
29 taken for the light to reach the target 24 and be
30 reflected back to the detector 30 by two, the distance
31 to the target 24 may be calculated.

32

33 A digital video camera 32 is bore-sighted with the
34 laser 12 (using the part-silvered prism 16). The
35 camera 32 is preferably a complementary metal-oxide
36 silicon (CMOS) camera which is formed on a silicon

1 chip. The chip generally includes all the necessary
2 drive circuitry for the camera. The camera 32 may be
3 a zoom CCD (charge coupled device) camera such as a
4 SONY EVI-371 which is designed for use in camcorders.
5 The CCD chip is provided with 752 by 582 image cells,
6 with a cell size in the order of 6.5 microns in the
7 horizontal direction and 6.25 microns in the vertical
8 direction. The lens can zoom from 5.4 millimetres (mm)
9 to 64.2mm focal length in 12 optical settings.

10

11 It should be noted that the camera 32 need not be bore-
12 sighted with the laser 12. Where the camera 32 is not
13 bore-sighted with the laser 12, the axis of the laser
14 12 will be offset from the axis of the camera 32 in the
15 x and/or y directions. The offset between these axes
16 can be calculated and the apparatus calibrated (eg
17 using software) to take account of these offsets.
18 However, where the camera 32 and the laser 12 are bore-
19 sighted (as in Fig. 1) there is no requirement to take
20 account of the offset in any subsequent calculations.
21 The camera 32 is advantageously capable of zoom
22 functions as this facilitates selection of targets at
23 distances up to, or in excess of, 1 km.

24

25 The transmit optics 20 serve a dual purpose and act as
26 a lens for the camera 32. Thus, light which enters the
27 transmit optics 20 is collimated and directed to the
28 camera 32 (shown schematically at 34) thereby producing
29 an image of the target 24 at the camera 32. The image
30 which the camera 32 receives is digitised and sent to a
31 processor (not shown in Fig. 1). It will be
32 appreciated that a separate lens may be provided for
33 the camera 32 if required.

34

35 The frame grabber may be of any suitable type, for
36 example a CREATIVE BLASTER IE500 imaging card (not

1 shown). This card digitises both fields of the
2 composite video input from the camera 32 and generates
3 a digital image therefrom.

4
5 Referring now to Figs 2 and 3, Fig. 2 shows
6 schematically a first embodiment of apparatus 100
7 mounted for movement in x and y directions (ie pan and
8 tilt), and Fig. 3 shows an exploded view of the
9 apparatus 100 of Fig. 2 in more detail.

10
11 Referring firstly to Fig. 2, the image capture and
12 laser transmitter and receiver unit 10 (Fig. 1) is
13 typically mounted within a casing 50. The casing 50 is
14 typically mounted to a U-shaped yoke 52, yoke 52 being
15 coupled to a vertical shaft 54. Shaft 54 is rotatably
16 mounted to facilitate rotational movement (indicated by
17 arrow 56 in Fig. 2) of the casing 50 in a horizontal
18 plane (indicated by axis 58) which is the x-direction
19 (ie pan). The rotational movement of the shaft 54 (and
20 thus the yoke 52 and casing 50) is controlled by a
21 motor 60 coupled to the shaft 54, typically via a
22 gearbox (not shown in Fig. 2). The operation of the
23 motor 60 is controlled by the computer.

24
25 The angle of rotation of the casing 50 in the
26 horizontal plane (ie panning of the unit 10 in the x-
27 direction) is measured accurately by a first digital
28 encoder 62, attached to the shaft 54 in a known manner,
29 which measures the angular displacement of the casing
30 50 (and thus the transmit laser beam 22) in the x-
31 direction.

32
33 Similarly, the yoke 52 allows the casing 50 (and thus
34 the transmit laser beam 22) to be displaced in the y-
35 direction as indicated by arrow 64. The casing 50 is
36 mounted to the yoke 52 via a horizontal shaft 66.

1 Shaft 66 is rotatably mounted to facilitate rotational
2 movement (indicated by arrow 64 in Fig. 2) of the
3 casing 50 in a vertical plane (indicated by axis 68)
4 which is the y-direction (ie tilt). The rotational
5 movement of the shaft 66 (and thus the yoke 52 and
6 casing 50) is controlled by a motor 68 coupled to the
7 shaft 56, typically via a gearbox (not shown in Fig.
8 2). The operation of the motor 66 is controlled by the
9 computer.

10

11 The angle of rotation of the casing 50 in the vertical
12 plane (ie tilting of the unit 10 in the y-direction) is
13 measured accurately by a second digital encoder 70,
14 attached to shaft 66 in a known manner, which measures
15 the angular displacement of the casing 50 (and thus the
16 transmit laser beam 22) in the y-direction. Thus, the
17 motors 60, 68 provide for panning and tilting of the
18 casing 50.

19

20 The output of the first and second encoders 62, 70 is
21 electrically coupled to the computer to provide a
22 feedback loop. The feedback loop is required because
23 the motors 60, 68 are typically coupled to the shafts
24 54, 66 via respective gearboxes and are thus not in
25 direct contact with the shafts 54, 66. This makes the
26 movement of the casing 50 which is effected by
27 operation of the motors 60, 68 less accurate. However,
28 as the encoders 62, 70 are coupled directly to their
29 respective shafts 54, 66 then the panning and tilting
30 of the casing in the x- and y-directions can be
31 measured more accurately, as will be described.

32

33 The embodiment of the image capture and laser
34 transmitter and receiver unit 10 shown in Fig. 2 is
35 slightly different from that illustrated in Fig. 1.
36 The camera 32 within unit 10 is not bore-sighted with

1 the laser 12, and thus casing 50 is provided with a
2 camera lens 72, a laser transmitter lens 74 and a laser
3 receiver lens 76. It should be noted that the laser
4 transmitter lens 74 and the camera lens 72 may be
5 integrated into a single lens as illustrated in Fig. 1.
6 Ideally, the camera lens 72, laser transmitter lens 74
7 and laser receiver lens 76 would be co-axial. This
8 could be achieved in practice by mechanically adjusting
9 the lenses 72, 74, 76 to make them co-axial. However,
10 this is a time consuming process and the offsets
11 between the lenses can be calculated and the apparatus
12 can be calibrated to take these offsets into account,
13 as will be described. This calibration is generally
14 simpler and quicker than mechanically aligning the
15 lenses 72, 74, 76.

16
17 Referring to Fig. 3, there is shown in more detail the
18 apparatus of Fig. 2. It should be noted that the
19 casing 50 which houses the image capture and laser
20 transmitter and receiver unit 10 is not provided with a
21 separate camera lens 72 (as in Fig. 2). It should also
22 be noted that the casing 50 in Fig. 3 is mounted to
23 facilitate rotational movement in the x-direction
24 (pan), but can be manually tilted in the y-direction
25 (tilt) or can be adapted to the configuration shown in
26 Fig. 2 for motorised pan and tilt.

27
28 As can be seen more clearly in Fig. 3, the casing 50 is
29 mounted to the U-shaped yoke 52. The yoke 52 is
30 coupled to the shaft 54 using any conventional means
31 such as screws 80. The shaft 54 is driven by the
32 stepper motor 60 via a worm/wheel drive gearbox 82.
33 The digital encoder 62 is provided underneath a plate
34 84 through which the shaft 54 passes and to which the
35 gearbox/motor assembly is attached. Plate 84 also
36 includes a rotary gear assembly 86 which is driven by

1 the motor 60 via the worm gearbox 82 to facilitate
2 rotational movement of the shaft 54.

3

4 The motor, gearbox and shaft assembly is mounted within
5 an aluminium casing 86, the casing 86 also having a
6 rack 88 mounted therein. The rack 88 contains the
7 necessary electronic circuitry for driving and
8 controlling the operation of the apparatus, and
9 includes a stepper motor driver board 90, a laser
10 control board 92 and an interface board 94.

11

12 The first and second digital encoders 62, 70 may be of
13 any conventional type, such as Moir Fringe, barcode or
14 mask. Moir fringe type encoders are typically used as
15 they are generally more accurate. Fig. 4 shows a
16 simplified schematic illustration of a digital encoder,
17 generally designated 110. Encoder 110 typically
18 comprises a casing 112 in which a disc 114 is rotatably
19 mounted. The disc 114 is provided with a pattern and
20 is typically at least partially translucent. The type
21 of pattern defined on the disc 114 determines the type
22 of encoder.

23

24 A light emitting diode (LED) 116 is suspended above the
25 disc 114 and emits a light beam (typically collimated
26 by a lens (not shown) which shines through the disc
27 114. The light emitted by the LED 116 is detected by a
28 detector, typically a cell array 118. As the disc 114
29 rotates (in conjunction with the shaft to which it is
30 coupled) a number of electrical outputs are generated
31 per revolution of the disc 114 by the cell array 118
32 which detects the light passing through the disc 114
33 from the LED 116. These types of encoders usually have
34 two output channels (only one shown in Fig. 4) and the
35 phase relationship between the two signals can be used
36 to determine the direction of rotation of the disc 114.

1

2 The encoder 110 produces a pulse output per unit of
3 revolution. Thus, as the disc 114 rotates, the pattern
4 on the disc 114 causes electrical pulses to be
5 generated by the cell array 118 in response to the
6 pattern on the disc 114. These pulses can be counted
7 and, given that one pulse is proportional to a certain
8 degree of rotation, the angular rotation of the disc
9 114 and thus the shaft 54 can be calculated.

10

11 In use, the unit 10 is typically externally triggered
12 by an input device such as a push button, keyboard,
13 penpad or the like. When the apparatus is triggered,
14 the camera 32 captures a digitised image of the target
15 area. The digitised image is made up of a plurality
16 of pixels, the exact number of which is dependent upon
17 the size of the image produced by the camera. Each
18 pixel has an associated x and y co-ordinate which
19 relate to individual positions in the target area. The
20 processor is then used to sequentially scan the laser
21 12 (by moving the part-silvered prism 16 accordingly,
22 or by using the motors 60, 68 in the Fig. 5 embodiment)
23 to measure the distance (range) to each successive
24 point in the target area given by the x and y co-
25 ordinates of the digitised image. This can then be
26 used to create three-dimensional co-ordinates (ie x, y
27 and z) to allow a three-dimensional image of the target
28 area to be produced, as will be described.

29

30 Fig. 5 shows the apparatus 100 (schematically
31 represented in Fig. 5 but shown more clearly in Figs 2
32 and 3) in use. The apparatus 100 is controlled and
33 operated using software installed on the computer
34 (shown schematically at 120) via a cable 122, telemetry
35 system or other remote or hardwired control. An image
36 of the target is displayed on the computer screen using

1 the camera 32 (Fig. 1) and is schematically shown as
2 image 124 in Fig. 5. When the image 124 of the target
3 area of interest is viewed on the screen, the user of
4 the apparatus 100 instructs the camera 32 (included as
5 part of the apparatus 100) to take a freeze frame image
6 of the target area. The freeze frame image 124 is a
7 digital image made up of a plurality of pixels and Fig.
8 6 is a schematic representation of the display produced
9 on the computer screen of the freeze frame image 124.
10 The image 124 is typically divided into an array of
11 pixels, with the image containing, for example, 200 by
12 200 pixels in the array.

13
14 Each pixel within the array has an x and y co-ordinate
15 associated with it using, for example, the centre C of
16 the picture as a reference point. Thus, each pixel
17 within the digital image can be individually addressed
18 using these x and y co-ordinates.

19
20 The individual addresses for each pixel allow the user
21 to select a particular object (for example a tree 126)
22 within the digital image 124. The tree 126 can be
23 selected using a mouse pointer for example, where the
24 mouse pointer is moved around the pixels of the digital
25 image by movement of a conventional mouse provided with
26 the computer in a known manner. The x and y co-
27 ordinates of each pixel may be displayed on the screen
28 as the mouse pointer is moved around the image.
29 Clicking the mouse button with the pointer on the tree
30 126 selects a particular pixel 128 within the array
31 which is identified by its x and y coordinates.

32
33 The computer is then used to calculate the horizontal
34 angle H_A and the vertical angle V_A (Fig. 6). The
35 horizontal angle H_A and the vertical angle V_A are the
36 relative angles between the centre point C of the image

1 and the pixel 128, as schematically shown in Fig. 6.

2
3 The methodology for calculating the horizontal angle H_A
4 and the vertical angle V_A from the pixel x , y co-
5 ordinates is as follows. Fig. 7 is a simplified
6 schematic diagram of inside the camera 32 which shows
7 the camera lens 72 and a charge-coupled device (CCD)
8 array 130. The camera 32 is typically a zoom camera
9 which therefore has a number of focal lengths which
10 vary as the lens 72 is moved towards and away from the
11 CCD array 130.

12
13 Referring to Fig. 7, the angles of horizontal and
14 vertical views, or the field of view in the horizontal
15 and vertical direction θ_H , θ_V (θ_V not shown in Fig. 7)
16 can be calibrated and calculated at different focal
17 lengths of the camera 32. For simplicity, it is
18 assumed that the CCD array 130 is square, and thus the
19 field of view in the horizontal and vertical directions
20 θ_H , θ_V will be the same, and thus only the field of view
21 in the horizontal direction θ_H will be considered. The
22 methodology described below considers one zoom position
23 only.

24
25 Having calculated (or otherwise obtained eg from the
26 specification of the camera 32) the field of view in
27 the horizontal direction θ_H then the principal distance
28 PD (in pixels) can be calculated. The principal
29 distance PD is defined as the distance from the plane
30 of the lens 72 to the image plane (ie the plane of the
31 CCD array 130).

32
33 Referring to Fig. 8, if the image width on the CCD
34 array is defined as H_R , then using basic trigonometry
35 $\tan(\theta_H/2) = H_R/(2PD)$. Thus,

36

1
$$PD = H_R / (2(\tan(\theta_H/2)))$$

2
3 If the distance between each pixel in the image 124 in
4 a certain unit (ie millimetres) is known, then the
5 principal distance PD can be converted into a distance
6 in terms of pixels. For example, if the field of view
7 in the horizontal and vertical angles θ_H , θ_V is, for
8 example 10° , and the image contains 200 by 200 pixels,
9 then moving one twentieth of a degree in the x or y
10 direction is the equivalent of moving one pixel in the
11 x or y direction.

12
13 When initially using the apparatus 100, the camera 32
14 is used to take a calibration freeze frame image and
15 the laser 12 is activated to return the range R to the
16 centre point C of the image. However, the laser axis
17 is typically offset from the camera axis. The
18 horizontal and vertical offsets between the laser axis
19 and the camera axis when the freeze frame image is
20 taken are defined as H_{offset} and V_{offset} and are known.
21 Knowing the range R and the horizontal and vertical
22 offsets H_{offset} , V_{offset} allows the offset horizontal and
23 vertical distances l_x and l_y in terms of pixels to be
24 calculated. Referring to Fig. 9, the centre point C of
25 the image 124 taken by the camera 32 and the laser spot
26 132 where the transmit laser beam 22 hits the target
27 area is typically offset by the horizontal and vertical
28 distances l_x and l_y .

29
30 Fig. 10 is a schematic representation illustrating the
31 horizontal offset H_{offset} outwith the camera 32, and Fig.
32 11 is a schematic representation illustrating the
33 horizontal distance l_x in terms of pixels, corresponding
34 to H_{offset} , within the camera 32. Referring to Figs 10
35 and 11 and using basic trigonometry,
36

1 $\tan \theta = H_{\text{offset}}/R$

2 and,

3 $l_x = PD(\tan \theta)$

4 Thus,

5 $l_x = PD(H_{\text{offset}}/R)$

6

7 and it follows that

8 $l_y = PD(V_{\text{offset}}/R)$

9

10 If the range to a certain object within the target area
11 (such as the tree 126 in Fig. 6) is required, then the
12 computer must calculate the horizontal and vertical
13 angles H_A , H_V through which the casing 50 and thus the
14 laser beam 22 must be moved in order to target the
15 object.

16

17 The user selects the particular pixel (relating to the
18 object of interest) within the image using a mouse
19 pointer. In Fig. 12, the selected object is
20 represented by pixel A which has coordinates (x, y) ,
21 and the laser spot 132 has coordinates (l_x, l_y)
22 calculated (eg by the computer 120) using the previous
23 method. The coordinates (x, y) of point A are already
24 known (by the computer 120) using the coordinates of
25 the pixel array of the image.

26

27 If the horizontal distance between pixel A and the
28 laser spot 132 is defined as d_x , and similarly the
29 vertical distance between pixel A and the laser spot
30 132 is defined as d_y , then

31

32 $d_x = x - l_x$

33 and

34 $d_y = y - l_y,$

35

36 and it follows that the horizontal and vertical angles

1 H_A , V_A can be calculated as

2

3 $H_A = \text{inverse tan } (d_x/PD)$

4

5 and

6 $V_A = \text{inverse tan } (d_y/PD)$.

7

8 Referring back to Fig. 2, having calculated the
9 horizontal and vertical angles H_A , V_A through which the
10 casing 50 must be rotated to measure the range to the
11 object A, the computer 120 instructs the motor 60 to
12 pan through an angle of H_A and simultaneously instructs
13 the motor 68 to tilt through an angle of V_A . Thus, the
14 transmit laser beam 22 is directed at the object A
15 selected by the user to determine the range to it.
16

17 However, the motors 60, 68 are not directly coupled to
18 the shafts 54, 66 (but via respective gearboxes) and
19 thus can have errors which results in the laser beam 22
20 not being directed precisely at the object A. However,
21 the encoders 62, 70 can be used to measure more
22 precisely the angles H_A and V_A through which the casing
23 50 was panned and tilted. If there is a difference
24 between the measured angles H_A and V_A and the angles
25 which were calculated as above, the computer can
26 correct for this and can pan the casing 50 through an
27 angle H_{AC} which is the difference between the calculated
28 angle H_A and the measured angle H_A , and similarly tilt
29 the casing 50 through an angle V_{AC} which is the
30 difference between the calculated angle V_A and the
31 measured angle V_A . The process can then be repeated by
32 using the encoders 62, 70 to check that the casing 50
33 has been panned and tilted through the angles H_{AC} and
34 V_{AC} . If there is a difference again, then the process
35 can be repeated to further correct for the errors
36 introduced. This iteration process can be continued

1 until the output from the encoders 62, 70 corresponds
2 to the correct angles H_A and V_A . The laser 12 is then
3 fired to give the range to the object A.

4
5 The calibration process described above is typically an
6 automated process for the calibration of the interior
7 and exterior parameters of the camera. The calibration
8 process typically determines the accuracy of the
9 measurements and the realism of the three dimensional
10 image produced. The main function of the calibration
11 process is to calibrate a principal point PP and the
12 principal distance PD using image-processing
13 techniques.

14
15 The principal point PP is based on the assumption that
16 the optical axis of the camera 32 is straight so that
17 the principal point PP for all zoom lenses falls at one
18 point on the image. When the camera 32 zooms in, the
19 targets on the image move towards the centre of the
20 image. The intersection of all target paths, whilst
21 zooming, is considered as the principal point PP. The
22 control program used for the automatic calibration
23 process enables the user to select targets whilst
24 zooming in and out. The processor then calculates the
25 average of the intersections of all target paths, which
26 is considered as the principal point PP. The principal
27 point PP is typically calculated several times and the
28 average of these calculations is taken to be the
29 principal point PP.

30
31 The principal distance PD varies with zoom lenses. At
32 each zoom position, the calibration begins with
33 pointing the apparatus 100 so that the central part of
34 the image is filled with the target area. The central
35 part of the image is typically a rectangle. The
36 angular readings of the apparatus (eg from the encoders

1 62, 70) are recorded. A pixel with the most unique
2 surrounding features within the central part is
3 selected as a target point and its image and
4 coordinates are recorded as described above. This
5 target point typically has the most features and should
6 be relatively easy to match.

7
8 The apparatus 100 is then panned and/or tilted to five
9 positions along the four main directions; that is up,
10 down, left and right. At each position, a
11 corresponding image is grabbed using the imaging card
12 (frame grabber) and the camera 32 and the angular
13 settings (eg from the encoders 62, 70) of the apparatus
14 100 are recorded. The central part of the image is
15 then moved to enclose the moved target point by best
16 estimate from the previous calibration data. The
17 target point is then searched and located with sub-
18 pixel precision by area-based matching techniques. A
19 check may be performed using, for example, back
20 matching to discard unreliable matchings. If both
21 horizontal and vertical directions have four matches
22 discarded in this manner, recalibration is suggested.
23 At least seven sets of locations of the target
24 (including the initial target location) with respect to
25 the angular settings of the apparatus 100 can be
26 obtained along the horizontal and vertical directions.
27 If the calibration results in the horizontal and
28 vertical directions are valid, the average value is
29 taken. A further check on the reliability of the
30 matching can be conducted on the basis of least squares
31 solution.

32
33 This calibration method can be conducted automatically
34 without the need for setting special targets which
35 enables the user to carry out the procedure at any
36 time. It also facilitates regular instrument check-up.

1 The automation without the use of set targets greatly
2 reduces the cost of the calibration and considerably
3 increases the ease of use of the calibration utility.
4

5 Referring again to Fig. 6, to obtain a three
6 dimensional (3D) image of the tree 126, the user can
7 select a number of pixels around the outline of the
8 tree 126. This selection limits the number of points
9 which are used to create a 3D image. It should be
10 noted however, that a 3D representation of the whole
11 image 124 can be created.
12

13 Having selected the outline of the target (ie tree
14 126), the software provided on the computer 120
15 instructs the motors 60, 68 to pan and tilt the unit 10
16 through respective horizontal and vertical angles H_A , V_A
17 corresponding to the pixels within the tree 126 (or the
18 entire image 124 as required). The same iterative
19 process as described above can be used to ensure that
20 the laser 12 is accurately directed to each of the
21 pixels sequentially. At each pixel, the laser 12 is
22 activated to obtain the range R to each of the pixels
23 within the tree 126, as previously described.
24

25 Once the horizontal and vertical angles H_A , V_A and the
26 range R of each of the pixels is known, the processor
27 within the computer 120 can then be used to calculate
28 the 3D co-ordinates of the pixels within the tree 126
29 to recreate a 3D image of the tree 126.
30

31 Referring to Fig. 14, the central laser spot 132 has an
32 offset l_x and l_y as described above, and also has
33 horizontal and vertical angles H_o , V_o and range R_o .

34 Determination of the pixel x and y coordinates p_x , p_y
35 for the point A which has horizontal and vertical
36 angles H, V and range R, can be done as follows using

basic trigonometry. It should be noted that the field of view in the horizontal and vertical directions θ_H , θ_V , the principal distance PD and the horizontal and vertical distances l_x and l_y are either all known or can be calculated as described above.

$$p_x - l_x = PD \tan(H - H_0)$$

and

$$p_y - l_y = PD \tan(V - V_0).$$

It thus follows that

$$p_x = l_x + PD \tan(H - H_0)$$

and

$$p_y = l_y + PD \tan(V - V_0).$$

Thereafter, the 3D coordinates x , y , z for the point A can be calculated, as will be described with reference to Fig. 15.

Using trigonometry,

$$x = R \cos V \cos H$$

$$y = -R \cos V \sin H$$

and

$$z = R \sin V$$

These calculations can then be repeated for each pixel (defined by p_x , p_y) to give 3D coordinates for each of the pixels within the target (ie tree 126 or image 124). An array of pixel co-ordinates p_x , p_y and the corresponding 3D coordinates x , y , z can be created and the processor within the computer 120 can be used to plot the 3D coordinates using appropriate software. Appendix A shows an exemplary array of pixel co-ordinates p_x , p_y and the corresponding 3D coordinates x ,

1 y, z of a bitmap image which can be used to generate a
2 3D image.

3
4 Once the 3D coordinates have been plotted, the software
5 then generates a profile of the 3D image using
6 triangles to connect each of the 3D coordinates
7 together, as shown in Fig. 16. Fig. 16 is a print of
8 the triangular framework used to recreate a 3D image of
9 a bitmap photograph. The bitmap image (ie the digital
10 image taken by the camera 32) is then superimposed on
11 the triangulated image to construct a 3D image of the
12 target (ie tree 126 or image 124). Fig. 17 shows a
13 print of a 3D image which used a bitmap photograph
14 superimposed on the framework of Fig. 16. The 3D image
15 of the target can typically be viewed from all angles
16 using the software. Thus, the user can effectively
17 walk around the tree 126. However, this may require a
18 number of photographs (ie digital bitmap images taken
19 by the camera 32) at different angles which can then be
20 superimposed upon one another to create a full 360° 3D
21 image. It should be noted that even when using only
22 one photograph, the user can manipulate the 3D image to
23 look at the tree 126 from all angles.

24
25 It should also be noted that having a bitmap (colour)
26 image of the tree 126 (and image 124) allows accurate
27 (true) colours to be assigned to each pixel within the
28 image. Conventionally, colours are assigned from a
29 palette which may not be the true and original colours.

30
31 The software may also be capable of allowing the user
32 to select two points within the tree 126 and
33 calculating the horizontal and vertical distances
34 between the two points. Thus, it is possible for the
35 user to determine, for example, the height of the tree
36 by using the mouse to select a pixel at the top and

1 bottom of the tree 126. If a building is plotted in 3D
2 using the above methodology, the software can be used
3 to determine the height, width and depth of the
4 building, and also other parameters such as the length
5 of a window, the height of a door and the like. To
6 enable the used to select points more accurately, the
7 software is advantageously provided with zoom
8 capabilities.

9
10 The software may also be capable of plotting the
11 profile of the tree using gradiented colours to show
12 the horizontal distance, vertical distance and/or range
13 to each of the pixels within the tree 126 or image 124.

14
15 Additionally, the software may be capable of allowing
16 the user to select one or more points whereby a profile
17 of the tree 126 in the plane selected can be shown.
18 Additionally, the profiles in the x, y and z directions
19 through one particular point within the image can also
20 be plotted. It is also possible for the x, y and z
21 axes to be superimposed on the image, and directional
22 axes (ie north, south, east and west) can also be
23 superimposed upon the image.

24
25 Instead of superimposing the bitmap (digital) image
26 over the triangular wireframe, the software may be used
27 to create a shaded image of the target and may also be
28 capable of changing the position of the light which
29 illuminates the target.

30
31 It will also be appreciated that the software can
32 generate x, y and/or z contours which may be
33 superimposed over the image.

34
35 Referring back to Fig. 5, the apparatus 100 can
36 optionally include a Global Positioning System (GPS)

1 (not shown). GPS is a satellite navigation system
2 which provides a three-dimensional position of the GPS
3 receiver (in this case mounted as part of the apparatus
4 100) and thus the position of the apparatus 100. The
5 GPS is used to calculate the position of the apparatus
6 100 anywhere in the world to within approximately ± 25
7 metres. The GPS calculates the position of the
8 apparatus 100 locally using radio/satellite broadcasts
9 which send differential correction signals to ± 1
10 metre. The GPS can also be used to record the time of
11 all measured data to 1 microsecond.

13 The apparatus 100 advantageously includes an
14 inclinometer (not shown) and a fluxgate compass (not
15 shown), both of which would be mounted within the
16 casing 50 (Fig. 2). The fluxgate compass generates a
17 signal which gives a bearing to the target and the
18 inclinometer generates a signal which gives the incline
19 angle to the target. These signals are preferably
20 digitised so that they are in a machine-readable form
21 for direct manipulation by the computer 120.

23 Thus, in addition to being used to find ranges to
24 specific targets, the apparatus may also be used to
25 determine the position of objects, such as electricity
26 pylons, buildings, trees or other man-made or natural
27 structures. The GPS system can be used to determine
28 the position of the apparatus 100 anywhere in the
29 world, which can be recorded. Optionally, the fluxgate
30 compass within the casing 50 measures the bearing to
31 the target, which can be used to determine the position
32 of the target using the reading from the GPS system and
33 the reading from the fluxgate compass.

35 The positional information, the bearing and the
36 inclination to the target can optionally be

[illegible]

1 user 154 anywhere in the world to within approximately
2 ± 25 metres. The DGPS calculates the position of the
3 user 154 locally using radio/satellite broadcasts which
4 send differential correction signals to ± 1 metre. The
5 GPS 158 can also be used to record the time of all
6 measured data to 1 microsecond.

7
8 The GPS 158 is coupled to a computer (similar to
9 computer 120 in Fig. 5) via a serial port. The
10 computer may be located in a backpack 160, shown
11 schematically in Fig. 18, or may be a portable
12 computer, such as a laptop. The backpack 160 has a
13 power source, such as a battery pack 162, either formed
14 integrally therewith, or as an external unit.

15
16 Mounted on the helmet 152 is a housing 164 which
17 encloses the range finder (as shown in Fig. 1), the
18 video camera 32, an inclinometer (not shown) and a
19 fluxgate compass (not shown). Signals from the range
20 finder, camera 32, compass and inclinometer are fed to
21 the computer in the backpack 160 via a wire harness
22 166.

23
24 The fluxgate compass generates a signal which gives a
25 bearing to the target and the inclinometer generates a
26 signal which gives the incline angle to the target.
27 These signals are preferably digitised so that they are
28 in a machine-readable form for direct manipulation by
29 the computer.

30
31 The video camera 32 is preferably a charge-coupled
32 device (CCD) camera. This type of camera operates
33 digitally and allows it to be directly interfaced to
34 the computer in the backpack 160. Signals from the
35 camera 32 are typically input to the computer via a
36 video card. The camera 32 may be, for example, a six-

1 times magnification, monochrome camera with laser
2 transmitter optics.

3

4 The view from the camera 32 is displayed on an eyepiece
5 VGA monitor 168 suspended from the helmet 152. The
6 monitor 168 is coupled to the computer in the backpack
7 160 via a second wire harness 170. The monitor 168 is
8 used to display computer graphics and a generated
9 graphics overlay.

10

11 The mounting of the monitor 168 on the helmet 152 is
12 independent of the housing 164 and is thus adjustable
13 to suit a plurality of individual users. A tri-axial
14 alignment bracket (not shown) is provided for this
15 purpose.

16

17 In use, software which is pre-loaded on the computer in
18 the backpack 160 enables the user 154 to see a video
19 image (provided by the camera 32) of the target on the
20 monitor 168. The software can overlay the video image
21 with a sighting graticule (not shown) and any measured
22 data in a separate window.

23

It should be noted from Fig. 1 that the camera 32 and the laser range finder are bore-sighted. Conventional systems use an offset eyepiece sighting arrangement with an axis which is aligned and collimated to be parallel to the axis of the laser range finder. However, use of the camera 32 (which displays an image of the target area on the VGA monitor eyepiece 168) bore-sighted with the laser range finder provides the user 154 with an exact view of the target area using the camera 32. Thus, there is no need for a collimated eyepiece and the user 154 can be sure that the range finder will be accurately directed at the target. To further improve accuracy, computer controlled graticule

1 offsets may be generated during a calibration and
2 collimation procedure to eliminate residual errors of
3 alignment between the laser range finder and the camera
4 32. These offset values may be stored in an erasable-
5 programmable-read-only-memory (EPROM) for repetitive
6 use.

7
8 Operation of the apparatus 150 is controlled by an
9 input device 172 connected to the computer via a
10 keyboard input. The input device 172 typically
11 comprises a keyboard, keypad, penpad or the like, and
12 controls different functions of the apparatus 150.

13
14 When an observation or survey is required of a
15 particular target area, the user 154 views the target
16 area using the camera 32 and the eyepiece monitor 168.
17 The target area is aligned with the graticule typically
18 using a small circle (not shown) or a cross as a guide.

19
20 The user 154 then fires the apparatus 150 using an
21 appropriate key or button on the input device 172. The
22 computer initiates the camera 32 which captures a
23 digital image of the target area and scans the laser 12
24 to provide a 3D image of the target area as previously
25 described. It should be noted that the panning and
26 tilting of the laser 12 is not achieved by motors 60,
27 68 as in the Fig. 2 embodiment. In this example, the
28 part-silvered prism 16 can be moved to scan the laser
29 over the target to provide range information for each
30 pixel within the target.

31
32 In addition, measurements of the various parameters
33 such as bearing and incline to the target area are
34 recorded, digitised and incorporated into the
35 calculations made by the computer. The global position
36 of the user 154 and the time of the measurement is also

1 situations.

2

3 Referring to Figs 19a to 19c, there is shown a vehicle
4 180 (such as a tank) which is provided with the
5 apparatus 100 of Figs 2 and 3 mounted on a telescopic
6 or extendable arm 182. As illustrated in Fig. 19a, the
7 apparatus 100 may be completely retracted when the
8 vehicle 180 is in motion, and may be stored behind an
9 armoured shield 184. The casing 50 of the apparatus
10 100 would tilt downwards to a horizontal attitude and
11 the telescopic arm 182 would extend so that the
12 apparatus 100 was substantially protected by the
13 armoured shield 184.

14

15 When the area to be surveyed is reached, the vehicle is
16 stopped and the apparatus 100 deployed on the
17 telescopic arm 182 by reversing the procedure described
18 above, as illustrated in Fig. 19b. The telescopic arm
19 182 is preferably mounted on a rotation joint 186 so
20 that the apparatus 100 can be rotated through 360° as
21 indicated by arrow 188 in the enlarged portion of Fig.
22 19b. A motor 190 is coupled to the rotation joint 186
23 to facilitate rotation of the joint 186. The apparatus
24 100 can typically be raised to a height of
25 approximately 15 metres or more, depending upon the
26 construction of the arm 182.

27

28 The particular configuration shown in Figs 19a and 19b
29 can accommodate large angles of roll and pitch of the
30 vehicle, such as that shown in Fig. 19c. In Fig. 19c,
31 the vehicle 180 is stationary on a slope 192 and has
32 been rolled through an angle indicated by arrow 185 in
33 Fig. 19c. The user or the computer can correct for the
34 angle of roll 185 by moving the arm 182 until the
35 inclinometer indicates that the apparatus 100 is level.
36 A level 198 (Figs 20a, 20b) may be provided on the base

1 images captured by the camera 32 to produce a 3D image
2 of the terrain, as described above.

3
4 The surveying operation can be done discretely and in a
5 very short time compared with conventional survey
6 techniques and provides a real-time 3D image of the
7 terrain. Once the terrain has been modelled, design
8 templates of equipment carried by the vehicle 180 (or
9 any other vehicle, aircraft etc) can be overlayed over
10 the image to assess which type of equipment is required
11 to cross the obstacle, such as a river.

12
13 Conventional techniques would typically require to
14 deploy a number of soldiers to survey the area manually
15 and report back. However, with the apparatus 100
16 deployed on the vehicle 180 the survey can be done
17 quicker, more accurately and more safely, without
18 substantial risk to human life.

19
20 It is possible to conduct multiple surveys with the
21 vehicle 180 in one or more locations, with the data
22 from each survey being integrated to give a more
23 accurate overall survey of the surrounding area.

24
25 Furthermore, if the arm 182 was disposed at the front
26 of the vehicle 160 as shown in Figs 21a and 21b, the
27 apparatus 100 can be used to check the profile of the
28 ground in front of the vehicle 180. Thus, the profile
29 of the ground could be shown in 3D which would allow
30 the driver of the vehicle (or other personnel) to
31 assess the terrain and warn of any dangers or
32 difficulties.

33
34 Alternatively, or additionally, the software on the
35 computer 120 could be used to generate a head-up video
36 display to which the driver of the vehicle 180 could

1 refer. The heading of the tank (measured by the
2 fluxgate compass) could also be displayed, with the
3 range to and height of the ground (and any
4 obstructions) in front of the vehicle 180 also being
5 displayed. The height displayed could be the height
6 relative to the vehicles' position, or could be the
7 absolute height obtained from the GPS 202.

8
9 Another application of the apparatus 110 would be to
10 capture images of electricity pylons for example by
11 targeting each individually and saving the data for
12 future reference (for example to allow their positions
13 on a map to be plotted or checked) or to observe them
14 in 3D to check for any faults or the like.

15
16 In addition to providing the 3D image of the target
17 area, the computer may also calculate the position of
18 the target area using the GPS/DGPS 158 (Fig. 18). The
19 position of the user 154 is recorded using the GPS/DGPS
20 158, and by using the measurements such as bearing and
21 inclination to the target area, the position of the
22 target area may thus be calculated.

23
24 The apparatus provides a 3D image of the target area
25 which, in a geographical format, may be used to update
26 map information and/or object dimensions and positions.
27 The software may overlay and annotate the measured
28 information on background maps which may be stored, for
29 example, on compact-disc-read-only-memory (CD-ROM) or
30 any other data base, such as Ordnance Survey maps.

31
32 Using a separate function on the input device 172, the
33 user can change the image on the monitor 168 to show
34 either a plot of the user's position (measured by the
35 GPS/DGPS 158) superimposed on the retrieved data base
36 map, or to view updated maps and/or object dimensions

1 and positions derived from the measurements taken by
2 the apparatus 100.

3
4 Fig. 22 shows a concept design of an alternative
5 apparatus 210. The apparatus 210 is mounted on a head
6 band 212 which rests on the head of a user 214.
7 Mounted on the headband 212 is a housing 224 which is
8 attached to the headband 212. The housing 224 encloses
9 the apparatus 100 (Fig. 5) as previously described.
10 This particular embodiment incorporates an eyepiece
11 monitor 250 into the housing 224.

12
13 Figs 23 to 30 show a hand-held housing for the
14 apparatus. The hand-held device 300 includes an
15 eyepiece 310 which is used to select the target area.
16 Device 300 includes an image capture and laser
17 transmitter and receiver unit 10 similar to that shown
18 schematically in Fig. 1.

19
20 In use, a user 314 (Figs 28 to 30) puts the eyepiece
21 310 to his eye and visualises the target through a lens
22 312. When the target has been visualised, a fire
23 button 315 is depressed which initiates the camera 32
24 (Fig. 1) to take a digital (two-dimensional) image of
25 the target, which can be displayed on a small LCD
26 screen 316. The laser range finder can then be used to
27 determine the range to each pixel using the methodology
28 described herein to allow a 3D image to be produced.
29 It should be noted that the hand-held device 300 need
30 not be capable of processing the 3D image. The range
31 to each pixel can be recorded and stored in a file for
32 transfer to a computer (provided with the appropriate
33 software) which may be used to reproduce the 3D image.
34 The device 300 is typically provided with a suitable
35 interface for downloading, or may be provided with an
36 alternative storage means such as an EPROM which may be

Modifications and improvements may be made to the foregoing without departing from the scope of the invention.